We Claim:

1.

A method for laser induced breakdown (LIB) of a material with a pulsed laser beam, the material being characterized by a relationship of fluence breakdown threshold versus laser pulse width that exhibits a rapid and distinct change in slope at a ~~predetermined~~ characteristic laser pulse width, said method comprising the steps of:

a. generating a beam of one or more laser pulses in which each pulse has a pulse width equal to or less than said ~~predetermined~~ characteristic laser pulse width; and

b. focusing said beam to a point at or beneath the surface of the material.

A

A

2.

The method according to claim 1 wherein the material is a metal, the pulse width is 10 to 10,000 femtoseconds, and the beam has an energy of 1 nanojoule to 1 microjoule.

A

3.

The method according to claim 1 wherein the laser beam defines a spot and has a lateral gaussian profile characterized in that fluence at or near the center of the beam spot is greater than the threshold fluence whereby the laser induced breakdown is ablation of an area within the spot.

Sub B1

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~~4.~~

The method according to claim ~~3~~ 33 wherein the spot size is a diffraction limited spot size providing an ablation cavity having a diameter less than the fundamental wavelength size.

~~5.~~

Sub A2

The method according to claim 1 wherein the material is transparent to laser wavelength and the pulse width is 10 to 10,000 femtoseconds, the beam has an energy of 10 nanojoules to 1 millijoule.

~~6.~~

Sub B2

The method according to claim 1 wherein the material is biological tissue, the pulse width is 10 to 10,000 femtoseconds and the beam has an energy of 10 nanojoules to 1 millijoule.

~~7.~~

Sub A3

The method according to claim 1 wherein the predetermined pulse width is obtained by measuring the ablation (LIB) threshold of the material as a function of pulse width and determining where the ablation (LIB) threshold function no longer scales as the square root of pulse width.

8.

The method according to claim 1 wherein the laser beam has an energy in a range of 10 nanojoules to 1 millijoule.

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9.

The method according to claim 1 wherein the laser beam has a fluence in a range of 100 millijoules per square centimeter to 100 joules per square centimeter.

10.

The method according to claim 1 wherein the laser beam defines a spot in or on the material and the LIB causes ablation of an area having a size smaller than the area of the spot.

11.

The method according to claim 1 wherein the laser beam has a wavelength in a range of 200 nanometers to 2 microns.

12.

The method according to claim 1 wherein the pulse width is in a range of a few picoseconds to femtoseconds.

Sub A1

13.

The method according to claim 1 wherein the breakdown includes chemical and physical changes.

14.

The method according to claim 1 wherein the breakdown includes chemical and physical breakdown.

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15.

The method according to claim 1 wherein the breakdown includes disintegration.

16.

The method according to claim 1 wherein the breakdown includes ablation.

17.

The method according to claim 1 wherein the breakdown includes vaporization.

18.

The method according to claim 1 wherein the spot size is varied by flexible diaphragm to a range of 1 to 100 microns.

19.

The method according to claim 1 wherein a mask is placed in the path of the beam to block a portion of the beam to cause the beam to assume a desired geometric configuration.

20.

The method according to claim 1 wherein the laser operating mode is non-TEMoo.

24 21.

A method for laser induced breakdown of a material which comprises:

a. generating a beam of one or more laser pulses ~~comprising a sequence of pulses.~~ in which each pulse has a pulse width equal to or less than a pulse width value corresponding to a change in slope of a curve of fluence breakdown threshold (F_{th}) as a function of laser pulse width (T), said change occurring at a point between first and second portions of said curve, said first portion spanning a range of relatively long pulse width where F_{th} varies with the square root of pulse width ($T^{½}$) and said second portion spanning a range of short pulse width relative to said first portion with a F_{th} versus T slope which differs from that of said first portion; and

A b. focusing said one or more pulses of said beam to a point at or beneath the surface of the material.

~~22~~ 25. The method according to claim ~~21~~ 24 and further including:

a. identifying a pulse width start point;

b. focussing the laser beam initial start point at or beneath the surface of the material; and

c. scanning said beam along a predetermined path in a transverse direction.

~~23.~~ 26.

The method according to claim ~~21~~ 24 and further including:

a. identifying a pulse width start point;

b. focussing the laser beam initial start point at or beneath the surface of the material; and

c. scanning said beam along a predetermined path in a longitudinal direction in the material to a depth smaller than the Rayleigh range.

Sub A5

~~24.~~

~~The method according to claim 21 wherein the breakdown includes chemical and physical changes.~~

~~25.~~

~~The method according to claim 21 wherein the breakdown includes chemical and physical breakdown.~~

~~26.~~ 29.

The method according to claim ~~21~~ 24 wherein the breakdown includes disintegration.

~~27.~~ 30.

The method according to claim ~~21~~ 24 wherein the breakdown includes ablation.

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~~28.~~ 36

The method according to claim ~~21~~ 24 wherein the breakdown includes vaporization.

~~29.~~ 37

A method for laser induced breakdown of a material which comprises:

a. determining, for a selected material, a characteristic curve of fluence breakdown threshold (F_{th}) as a function of laser pulse width;

b. identifying a pulse width value on said curve corresponding to a rapid and distinct change in slope of said F_{th} versus pulse width curve characteristic of said material;

c. generating a beam of one or more laser pulses, said ~~beam comprising a sequence of pulses~~ having a pulse width at or below said pulse width value corresponding to said distinct change in slope; and

d. focusing said one or more pulses of ~~said beam~~ to a point at or beneath the surface of the material.

~~30.~~ 38

The method according to claim ~~29~~ 37 and further including:

a. identifying a pulse width start point;

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b. focussing the laser beam initial start point at or beneath the surface of the material; and

c. scanning said beam along a predetermined path in a transverse direction.

39 ~~31~~.

The method according to claim ~~29~~ 37 and further including:

a. identifying a pulse width start point;

b. focussing the laser beam initial start point at or beneath the surface of the material; and

c. scanning said beam along a predetermined path in a longitudinal direction in the material to a depth smaller than the Rayleigh range.

Sub A4

~~32.~~

~~The method according to claim 29 wherein the breakdown includes chemical and physical changes.~~

~~33.~~

~~The method according to claim 29 wherein the breakdown includes chemical and physical breakdown.~~

42 ~~34~~.

The method according to claim ~~29~~ 37 wherein the breakdown includes disintegration.

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43 ~~35.~~

The method according to claim 37 ~~29~~ wherein the breakdown includes ablation.

44 ~~36.~~

The method according to claim 37 ~~29~~ wherein the breakdown includes vaporization.

Sub B7 A

~~37.~~

The method according to any one of claims 1, 2, 5, 6, 21, or ~~and~~ 29 wherein said beam is obtained by chirped-pulse amplification (CPA) means comprising means for generating a short optical pulse having a predetermined duration; means for stretching such optical pulse in time; means for amplifying such time-stretched optical pulse including solid state amplifying media; and means for recompressing such amplified pulse to ~~its~~ desired ~~original~~ duration. J.S., SKD. X.L. G.M. D.D PRL

3 ~~38.~~

The method according to claim 1 wherein the spot size is varied within a range of 1 to 100 microns by changing the f number of the laser beam. J.S. SKD. X.L G.M D.D. PRL

41 ~~34.~~

The method according to claim 1 wherein the spot size is varied within a range of 1 to 100 microns by varying the target position.

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Add A7

Add B9

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